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Technical Proposal

Measurements of PM_{10} and $PM_{2.5}$ Emission Factors from Paved Roads in California

Solicited Proposal Prepared for:
State of California Air Resources Board
Research Division
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Statement of Significance

Many air basins in California are not in compliance with the State and Federal standards for suspended particulate matter (PM). To form effective control measures it is necessary to determine the magnitude of the various PM sources that contribute to the overall emission inventory. The component of PM due to suspended soil (crustal material) can be determined from the chemical composition of PM sampled from ambient air. The crustal material may originate from a wide variety of sources that cause soil to become entrained in the air. These sources, such as motor vehicle operation, agricultural practices, and construction, cannot be distinguished since they all involve suspending soil. The emission factors from these sources are also difficult to quantify since they are dispersed immediately at their points of origin and therefore do not emanate from a duct from which concentrations could be measured. Empirical equations have been developed that relate emission rates with other more easily measurable parameters. For paved roads the emission factor equation is based on the silt loading of the roads. Using the emission equation for paved roads, it has been estimated that these sources can account for a major portion of the crustal PM in California where the standards are exceeded.

The emission equation recommended by EPA (AP-42) was developed from measuring upwind and downwind PM concentrations from roads located primarily in the Midwest. Applying this approach to roads in California resulted in much lower emission rate than that predicted from the AP-42 equation. In many instances the difference in PM_{10} concentrations (particles less than 10 μm aerodynamic diameter) between upwind and downwind locations was near the measurement precision of filter sampling. This primary objective of this proposal is to more accurately characterize PM emission rates from vehicles on paved roads in California. Our PM measurement approach will be based on real-time optical sensors rather than filter collection. This approach allows greater measurement sensitivity, the collection of much more data in a given period of time for a more robust data set, and the ability to characterize emissions as a function of vehicle operating parameters and road surface condition.

Abstract

The emission factors of PM$_{10}$ and PM$_{2.5}$ (particulate matter less than 10 and 2.5 μm aerodynamic diameter, respectively) for vehicles operated on paved roads in California will be characterized by a three-way approach. The primary measurement device in all three will be sensors based on the optical scattering of light. These instruments will be calibrated against PM concentrations determined from filter collection followed by mass weighing. In the first approach, we will conduct a long-term monitoring program collecting PM concentration data on both sides of an arterial roadway. Concurrently obtained meteorology will be used to estimate emission factors from a recently developed dispersion model. The long term nature of the project coupled with real-time concentration measurements will allow a great many emission factor determinations and therefore significantly reduce the uncertainty of the result. In the second approach, we will determine PM concentrations directly in a vehicle's plume using an instrumented vehicle with a trailer. The PM concentrations at this sampling point are expected to be nearly an order of magnitude higher than those from sampling at the roadside, again reducing the uncertainty of the measurements. The real-time measurements will also allow determining emission factors as a function of the road surface and the vehicle's speed, weight, size, and shape. The final approach will determine the effect of trackout, an upset condition where soil is directly deposited on the road's surface. The emissions from this roadway condition, which commonly occurs about construction sites, will be determined as a function of the soil applied, time on the roadway, and the number of vehicles passing over the area.

1. Background and Objectives

1.1 Background

Many areas in the State of California consistently exceed both the State and Federal PM_{10} air quality standards, and they are expected to exceed the new $PM_{2.5}$ standards. To formulate effective mitigation approaches, the sources of the PM must be accurately known. Receptor modeling has shown that PM_{10} of geologic origin is often a significant contributor to the concentrations in areas that are in non-attainment (Chow et al., 1992). A significant portion of this geologic material has been estimated to originate from paved roads (Zimmer et al., 1992; Gaffney, 1996). A number of studies have been conducted to determine the contribution of paved roads to measured concentrations of PM_{10} (Venkatram and Fitz, 1998; Ashbaugh et al., 1996; Harding and Lawson, 1996; Kantamaneni et al., 1996; Claiborn et al., 1995; U.S. EPA, 1993; Zimmer et al., 1992; Cowherd and Englehart, 1984). These studies used upwind-downwind sampling by filtration to determine the net mass emission due to the roadway.

The studies conducted by Cowherd and co-workers primarily in the Midwest resulted in an empirical expression relating the PM emission rate with the silt loading of the road. This expression was incorporated into the EPA document AP-42 for predicting emission rates and has been widely used all over the country to estimate the fraction of PM_{10} originating from roads:

$$e = 0.9(sL)^{0.65}W^{1.5}\ (g/VKT) \tag{1}$$

where

e = PM_{10} emission factor in units shown above

s = surface silt content as fraction of material smaller than 75μm in diameter

L = total surface loading in gm/m^2

W = Mean vehicle weight in tons

VKT = vehicle kilometers travelled

The AP-42 model explains a small fraction of the variance of the data from which it is derived. Since it lacks a mechanistic basis, it is difficult to justify extrapolating the model to conditions different from those of the data used to derive it. Extrapolation can lead to large errors in emission estimates as shown by McCaldin and Heidel (1978).

Equation (1) was derived by measuring the total flux across roadways using a PM_{10} monitoring array and based solely on surface silt loading. If the silt loading were decreased by sweeping, PM_{10} emissions would be expected to decrease proportionately. The EPA has estimated that a thorough sweeping program could reduce the emissions from paved roads by approximately one third. In a study conducted in Reno, NV, however, no relationship was observed between sweeping streets and ambient PM_{10} concentrations. This lack of relationship could be caused by the emissions created during the sweeping process canceling out the expected benefits. We have recently quantified the emission rates of regenerative sweepers similar to those used in the Reno study and found them to be insignificant compared with the silt removed (Fitz, 1998). Another explanation is that the silt loading is rapidly replaced after sweeping to an equilibrium level dependent on factors such as vehicle speed and density. A third explanation is that the Reno study was not sufficiently sensitive to detect a change.

We recently conducted a study to measure and model the PM$_{10}$ emissions from paved roads in southern California (Venkatram and Fitz, 1998). Emission factors were measured by making filter-based PM$_{10}$ measurement upwind and downwind of several types of paved roads. In most instances, the differences in concentrations were very close or at the measured precision of the measurement method. The resulted in a large amount of error when calculating the emission factors from a modeling approach. Silt measurements were made concurrently for a number of the tests. There was no correlation between silt loading and the estimated emission factors. Silt loadings were generally lower than those suggested as defaults in AP-42. This is not unexpected since many of the roads in southern California do not have a significant source of crustal material to create emissions. The silt loadings are likely to rapidly equilibrate at a low level due to the effective "vacuuming" from the vehicle's wake or motion of the tire. Nicholson and Branson (1990) observed this rapid attainment of equilibrium when particles tagged with a fluorescent dye were deposited on a road and monitored.

As an extension of this program, we performed measurements before and after sweeping the streets (Fitz, 1998). Even on a street that is not routinely swept, there was not significant change in either the PM$_{10}$ emission factor or in the silt loading of the active traffic lane.
Because emissions from a fugitive source cannot be measured directly, they must be inferred This is usually achieved by one of the following methods:

- by estimating the flux of material through a horizontal plane downwind of the source (US EPA, 1984a), or

- by fitting a dispersion model to measurements of concentrations and winds (Dyck and Stukel, 1976; McCaldin and Heidel, 1978) made at locations downwind of the source; the emission rate is essentially the parameter that results from this analysis.

In principle, the calculation of horizontal flux can be an accurate method if the sampling density is sufficient to capture most of the material leaving the fugitive source. In practice, this type of sampling can be difficult because of the required sampling density. It also involves measurements of low winds close to the ground where the highest concentrations occur. To get around this, one is forced to make assumptions about the behavior of the concentrations and wind velocities near the ground. For example, US EPA (1984a) assumed that the flux at the ground was equal to that at 1m. The validity of this assumption has not been justified. The flux measurement depends on good coverage of several downwind locations using profilers. Most studies to date have used only one profiler.

The second method of inferring emissions involves fitting a dispersion model to a small set of concentration measurements. The accuracy of the method depends upon information on wind speed, release height, and vertical plume spread, and a physically realistic dispersion model applicable to surface releases. It is easy to see that this information can be highly uncertain. First, the selection of the appropriate wind speed poses a problem because the value of the wind at the surface is zero. To avoid this problem, we can select a release height at which the velocity is specified. We have a similar problem with the vertical plume spread, unless it can be inferred from measurements or calculated from another model. These uncertainties with the use of a dispersion model to estimate emissions have not been considered in most studies conducted to date (for example, Dyck and Stukel, 1978; Zimmer et al., 1992). Even when the dispersion model represents the state of the art and the measurements are high quality, Hanna (1990) showed that this procedure is associated with a great deal of uncertainty. When the dispersion model was based on state-of-the-art similarity theory, the error in emission calculations was about 30%. When a conventional Gaussian dispersion model was used, this error was over 100%. This suggests the need for independent estimates of emissions to reduce uncertainty.

1.2 Objectives

The primary objective of this project is to make more accurate estimates of PM$_{2.5}$ and PM$_{10}$ emission factors from paved roads. The data collected will allow more accurate estimates than those possible using the AP-42 approach. Specifically, we will attempt the following:

- Determine PM$_{2.5}$ and PM$_{10}$ emission factors from roadways using real-time upwind-downwind measurements.
- Characterize the emissions from individual vehicles over a wide range of parameters such as vehicle speed, weight and shape for various types of roadways.
- Determine the PM emission rate from trackout of crustal material from unpaved to paved areas

2. Approach

There are two major differences in our approach compared with previous studies. First, we will use real-time measurement methods. While these are optically based and do not directly measure PM$_{10}$, they have been found to be highly correlated with direct measurements. These instruments are more sensitive than mass-based methods and allow for immediate feedback to guide experimental procedures. One such instrument is the DustLite Model 3000 Aerosol Monitor manufactured by Rupprecht and Patashnick. This instrument is battery operated and has a resolution of 1 $\mu g/m^3$ with a time constant of 1 second. It comes with inlets for both PM$_{2.5}$ and PM$_{10}$.

The second major difference is that we will make measurements on moving vehicles to characterize the emissions under a wide variety of driving conditions. This approach has several advantages. First, the concentrations are much higher when nearer to the source. The second advantage is that dispersion modeling is not needed since the monitoring is done before dispersion occurs to any significant degree. We will characterize the PM distribution within the wake of the vehicle and use these data to determine the emission rate in g/VKT by diving the PM concentration by the wake volume. Combining the real-time measurements on a moving vehicle also allows the rapid collection of data over a wide variety of vehicle operating parameters.

2.1 Upwind-Downwind Real-Time PM Measurements

Previous upwind downwind measurements made in southern California were not sufficiently precise to accurately determine PM_{10} emission factors. This is likely due to roads in this region being generally cleaner than those used, primarily in the Midwest, to develop the AP-42 model. The use of real-time optical analyzers rather than collecting and weighing filters offers a number of advantages. Unlike the integrated measurements of a filter, the real-time measurements allow the "puff" of the emission to be measured, resulting in a greater signal for a given noise. At the same time of the "puff" we will be able to determine the wind speed and direction and determine if and exactly when the upwind measurement was in the same air mass as the downwind measurement. The real-time measurement approach also allows for long-term monitoring with little operator intervention. Thus, it is practical to monitor differences for several months with the same labor as for several days. It is likely that relatively rare specific events cause short-lived periods of high PM_{10} emissions. These are easily missed when measurements are made for only several days. We are not aware of any other such long-term measurements reported in California or any other location. The approach will produce a robust data set with varying traffic and weather conditions.

Three-component wind speed will be determined at three elevations (1, 5, and 10m). Relative humidity, temperature and total solar radiation will also be measured. A Campbell CR10 data logger will be used to collect 1-minute averaged data.

We will calibrate the optically based real-time measurements with mass determinations from filter collection at both the downwind and upwind sites. This is necessary since the response of these instruments is dependent on the size distribution of the particulate matter being measured. For PM_{10} a Graseby-Andersen model 246B inlet will be used, but modified so that it attaches directly to a 47mm filter holder. For $PM_{2.5}$ a Sensidyne model 240 cyclone inlet will be attached directly to a closed face 47mm filter holder. Gelman Teflo filters will be used for both samplers. A Cahn model 34 microbalance will be used to determine the weight of the filters before and after sampling to within $\pm$ 1 μg. All filters will be equilibrated to 15°C and 50% RH for 24 hours prior to weighing.

The logistics of finding appropriate upwind and downwind monitoring sites are complicated by the need of security and power in addition to an appropriate perpendicular alignment with the prevailing wind. We have found such a site from previous studies that meets these criteria. Canyon Crest Drive is a north-south street that bisects the UC Riverside campus in the Agricultural Operations area. These are open fields that are enclosed with cyclone fencing for security. Power is available nearby to both sides of the road, and samplers can be placed to within 10 feet of the curb. We will perform daily site checks. We will determine whether street sweeping has been conducted by depositing dirt in the gutter and checking daily to see if it has been removed. We have found this to be a much more reliable approach than the schedule of the sweeper operator.

2.2 On-Vehicle Real-Time PM Emission Measurements

Rather than upwind-downwind sampling to measure fugitive PM_{10} emissions from vehicles, we propose a more direct approach. This will involve sampling directly in the wake of a moving vehicle. To our knowledge, the use of this approach has not been previously published. This will be accomplished in three phases. The first phase will involve feasibility testing, the second method evaluation under controlled conditions, while the third phase will utilize actual roadways.

- **Feasibility Testing**

To determine whether this approach is feasible, we need to estimate the concentration in a vehicle's wake. Our observations of vehicles traveling on unpaved roads show that the plume does not appreciably disperse for several car lengths. Considering that the wake is two meters square, then the volume of one kilometer of wake would be 4000 m^3. In previous studies, we and others have estimated the lower limit emission factor of 0.1g VKT (vehicle kilometer traveled) on high-speed, high-traffic-count paved roads. Using this emission factor, the plume from the wake would have a concentration of 25 $\mu g/m^3$. Given this plume concentration, ambient background, and subsequent dispersion, it is understandable why downwind PM measurements are typically only several $\mu g/m^3$ higher than upwind. Monitors that measure light scattering to determine PM concentrations would easily measure these plume concentrations. Two examples are Rupprecht and Patashnick's DustLite Model 3000 Aerosol Monitor and Thermo Systems Inc.'s DustTrak. Mass concentrations could also be determined by filtration, although a low ambient background and sampling at least 1 m^3 of air would be desirable. With a maximum flow rate of approximately 140 L/min through 47mm membrane filters, sufficient sample could be collected in about 10 minutes from a single vehicle under these conditions.

The concept of using real-time PM concentration monitors mounted aboard a vehicle to determine the emission factors from mobile sources has not yet, to our knowledge, been reported. We therefore propose a limited study to characterize this approach with respect to sensitivity and instrument durability. To do this we will outfit a passenger vehicle with a PM_{10} DustLite and connect the inlet to one of two fixed monitoring points, one in front of the vehicle and one after. We will drive laps at constant speed on a test track selected for low background PM concentrations. Each lap will require approximately ten minutes to complete, at which time the probe location will be moved to the other sampling point. A data logger will be used to record one-minute averaged data. A minimum of twelve laps will be completed. The data will be compiled into two sets, corresponding to each sampling position. The variability of the measurements will be assessed by the standard deviation of each set, while a Wilcoxan non-parametric statistical test will be applied to determine if the data sets are different at the 95% confidence level and if the mean concentration behind the vehicle is greater than at the front. The experiment will be repeated with a DustTrak for selecting the most appropriate instrument.

- **Sampling Inlet Characterization**

Collecting particulate samples from a vehicle moving at speeds of a few mph to 70 mph will require pre-inlets to minimize anisokinetic sampling that result from the air flow. Although we will perform a literature search to determine if there are better alternatives, we propose using one of two approaches. The objective is to perform a precut prior to the inlets for cutting $PM_{2.5}$ and PM_{10}. The favored approach is a design that uses a diffuser consisting of a hemisphere with many small holes (Kalatoor et al., 1995) The second approach uses a coarse Nuclepore filter to remove particles larger than 15 um-aerodynamic diameter (Cahill et al., 1977). For the $PM_{2.5}$ and PM_{10} size cuts we will use the inlets supplied by the manufacturer of the dust monitor. Sample will be directed from the pre-inlet to the monitor using the shortest length of ¾ inch diameter copper tubing possible. We will evaluate both the DustLite and DustTrak with inlets for $PM_{2.5}$ and PM_{10} collection by operating them on the front of a test vehicle while it makes wide circles standard low volume $PM_{2.5}$ and PM_{10} samplers. We will use the inlet device and monitor that most closely agrees with the stationary low volume samplers. In the following descriptions we will refer to the DustLite as the PM monitor, although the performance data will be used to select the actual brand.

- **Characterization of the Vehicle Wake and Sampling Point Optimization**

To determine where in the vehicle wake to collect samples, the PM concentrations in the vehicle wake must be characterized. To do this we propose sampling on an asphalt surface upon which an even layer of particles of known size has been deposited. This will provide high PM_{10} concentrations of aerosolized particles typical of an unpaved roadway, but without the rocks and debris of actual unpaved roads. A previous study has shown that such an application on weathered asphalt should be useful for dozens of test passes (Sehmel, 1973). Potential particles will be inert materials such as diatomaceous earth, clay, flour, or minerals. Measurements will be made at a number of sampling points held in place with a small trailer towed by an electric or natural gas powered vehicle (to minimize interference from the exhaust). The trailer will consist only of sufficient framing to attach sampling inlets and associated pumping hardware. The design will focus on minimizing the aerodynamic influence of the trailer with respect to the vehicle's wake. The sampling system will consist of a network of sampling positions distributed along the length, width and height to fully sample the plume created by the vehicle as it traverses the test roadway. The tubing from each sampling point will be of identical length and lead to the tow vehicle containing the DustLite. The tubing will be manually interfaced to the DustLite to obtain sequential samples at each test point.

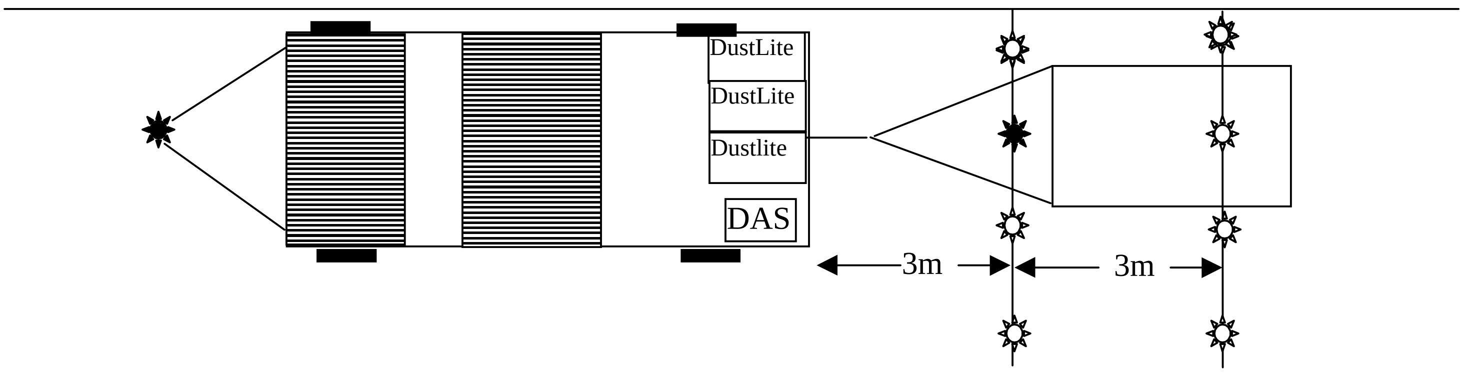
For this initial testing, size-selective inlets will be unnecessary, as the test material distributed on the roadway will all be less than or nearly equal to 10 microns aerodynamic diameter. Since the wake is expected to be quite turbulent, isokinetic sampling will not be possible to achieve. We will estimate sampling error by operating otherwise identically placed inlets facing both in and opposed to the direction of the vehicle. We will then determine the extent of sampling bias induced by the inlet positioning.

The trailer will have a matrix of sampling positions at three horizontal planes with each horizontal plane consisting of ten sampling positions. There are then a total of 30 rear sampling positions (Figure 2-1). The width of the sampling array should characterize the limits of the wake. Two vertical sampling arrays are included as a matter of QC (to determine whether the emission factor can be reproduced at both distances back), and we may not know which distance might be the best as far as capturing all of a well mixed wake. Three DustLites will be used for the initial testing, two at fixed positions for reference (front and rear) and a third for mapping the PM concentrations of the vehicle's wake. We will determine the concentration profile of the wake at six speeds, starting at 20 mph and increasing to 70 mph in 10-mph increments.

Once we have determined the flow/concentration pattern of the vehicle on the test track, we will choose the most representative position to sample based on vehicle speed and collocate inlets at these positions. We then measure emission factors under controlled conditions using both this sampling array and an upwind-downwind sampling array, each array sampling at 1, 3, 5, and 10 meters above the ground. This will allow us to compare the two approaches under the high emission levels generated from the dosed test track.

The final use of the test track will involve repeated runs at a single speed after a single application of particulate material to the test track. This will determine how effective vehicles are in removing deposited materials from the roadway. Since we will know how much test particulate was initially deposited, we will also be able to determine if the measured emission factors agree with the applied amount of particulate to the roadway.

Figure 2-1. Sampling Configuration.



DustLite, Inlet, mapping
Dustlite Inlet, Reference

Table 2-1 shows the full sampling matrix proposed for the testing of the mobile measurement platform. With this matrix we will determine:

- The comparability with the PM$_{2.5}$ mass collection methods.
- The precision of the measurement (with all three DustLites sampling from the same point).
- The homogeneity of the PM within the vehicle's wake with respect to the vehicle's speed.
- The vertical and horizontal extent of the plume as a function of vehicle speed and cross wind and the need to sample higher and wider.
- The optimum sampling position.

The full sampling of two vertical planes will allow us to estimate the uncertainty of the measurement approach by allowing an independent measurement of the emission factor.

Table 2-1. Vehicle Wake Characterization Test Matrix.

Reference Vehicle Characterization Test Matrix

Speed/Traffic	Winds	TEOM Front Data Points	TEOM Back Data Points	TEOM 1-29 Data Points	Total Tests	TEOM Total Data Points	Comments
20	Light	29	29	29	29	87	AM at Test Track
30	Light	29	29	29	29	87	AM at Test Track
40	Light	29	29	29	29	87	AM at Test Track
50	Light	29	29	29	29	87	AM at Test Track
60	Light	29	29	29	29	87	AM at Test Track
70	Light	29	29	29	29	87	AM at Test Track
20	Moderate Cross	29	29	29	29	87	PM at Test Track
30	Moderate Cross	29	29	29	29	87	PM at Test Track
40	Moderate Cross	29	29	29	29	87	PM at Test Track
50	Moderate Cross	29	29	29	29	87	PM at Test Track
60	Moderate Cross	29	29	29	29	87	PM at Test Track
70	Moderate Cross	29	29	29	29	87	PM at Test Track

- Field Measurements

Once the initial characterization experiments have been performed, we will perform a test of the system with the rear sampling point located in what we justify as the optimum position.

The vehicle will be equipped with sensors to measure temperature, relative humidity, total solar radiation, vehicle speed, and location (using a global positioning system or GPS). We will also include a sensor to determine when the brakes are applied as this may have an effect on the PM emissions. A Campbell CR10 data logger will be used to collect all data at intervals varying from 1 to 60 seconds.

We will then perform a full-scale test of the test vehicle in the Riverside area to determine the sensitivity of the technique. This area is appropriate as the silt loadings and emission factors for the area are generally lower than the average for the country and the background concentration will be the highest. If we find sufficient sensitivity under these conditions, the method would be suitable for any other location. We will initially test the vehicle with at the fixed site to determine how the two techniques compare by repeatedly driving past the fixed monitors. At the same time we will determine the silt loading of the roadway using the vacuuming method described in AP-42. We will then characterize a number of different types of roadways and driving conditions. At a minimum the following will be evaluated:

Freeway peak traffic
Freeway off-peak traffic
Arterial peak traffic
Arterial off-peak traffic

Local roads
Intersections

The tests will be done first with PM$_{10}$ inlets (the size range in which the greatest difference between front and rear in PM concentrations is expected) and then repeated after installing PM$_{2.5}$ inlets.

We also will evaluate the use of the test vehicle to sample the dust plume produced by other vehicles. This will be done under light traffic conditions to minimize the interference from other vehicles. Driving next to and in front of another type of vehicle (a heavy duty truck for example) the background PM response, and then dropping back and to the rear of the other vehicle. This approach will be used with both PM$_{2.5}$ and PM$_{10}$ inlets for a variety of test vehicles, speeds, and roadway types.

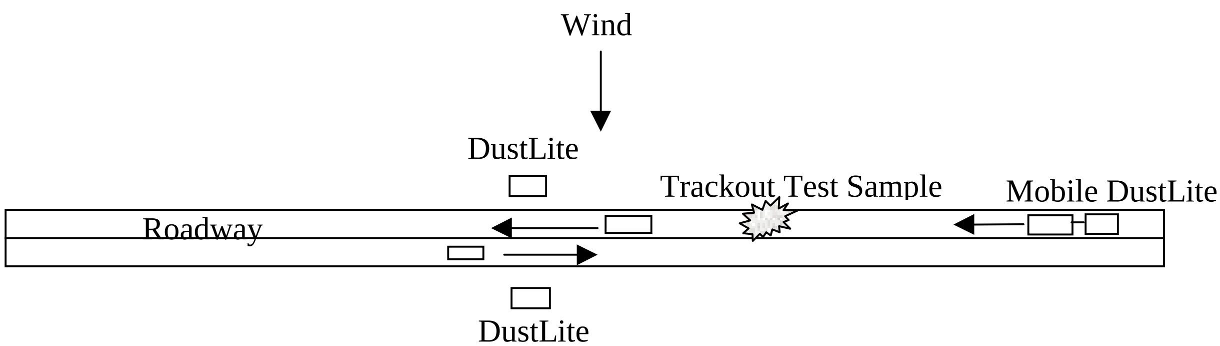
The data from this study will be reviewed to determine the range of emission factors and compare them with previous studies conducted in this area by us and others. We will also estimate the uncertainty of the measurements and make further recommendations for implementing this technique.

2.3 Trackout PM Emission Measurements

The impact of trackout emission will be determined using a combination of fixed and mobile PM$_{10}$ monitoring after the mobile monitoring positions have been optimized. Trackout experiments will be performed at the fixed site used for long-term upwind-downwind measurements. Trackout will be applied to the upwind lane of the roadway by at least two typical methods. One will use a vehicle to track through mud and pull out onto the roadway approximately 50 m from the monitoring location. The mass of crustal material will be characterized by several tests in which the application is immediately swept up and weighed. In the second approach, a weighed amount of material will be spread on the roadway, simulating drop-off. The monitoring vehicle, with the rear DustLite sampling inlet located at an optimum point on the trailer, will initially be located at a stationary position up traffic from the deposit. Figure 2-2 shows the experimental layout.

The PM emissions from the roadway will be characterized by operating the test vehicle for a number of passes of the trackout site prior to application. After the trackout is applied, we will drive the test vehicle over it a number of times to determine the affect on the PM$_{2.5}$ and PM$_{10}$ emission factors. The test vehicle will then be operated sufficiently long to characterize the time period that the trackout has a significant affect on the emissions. The time interval between test runs will be adjusted depending on the rate of emission decline.

Figure 2-2. Layout to Determine the PM$_{10}$ Emission Effect of Trackout.



3. Scope of Work

The detailed approach was described in the previous section. This section describes the scope of the work and the treatment of the data obtained.

3.1 Work Plan

Planning, management, and performance of this study will be guided by a Work Plan prepared in a format following guidelines for an EPA Category II Quality Assurance Project Plan (QAPP) (U.S. EPA, 1984). It will be submitted to the ARB for review and approval prior to commencing measurement activities. The key elements of the Work Plan are shown in Table 3-1. This project involves three fairly distinct areas of activity: preparation and training, field measurement, and data validation. The Work Plan will be for the project overall and will describe the QA/QC activities for each of these components.

3.2 Upwind-Downwind Real-Time PM Measurements

A monitoring station will be set up to collect meteorological data and real-time PM$_{2.5}$ and PM$_{10}$ concentrations on both sides of an arterial road for a minimum of four months, representing different seasons. For a minimum of ten selected daytime periods we will calculate the PM$_{2.5}$ and PM$_{10}$ emission factors for vehicles using our dispersion model (Venkatram et al., 1999).

Table 3-1. Elements of the Quality Assurance Project Plan

1.	Project Description
2.	Project Organization and Responsibilities
3.	Data Quality Indicators and Goals
4.	Measurement Procedures
5.	Calibration Procedures and Frequency
6.	Data Reduction, Validation, and Reporting
9.	Internal QC Checks
10.	Internal Performance and System Audits
11.	Instrument Preventive maintenance
12.	Calculation of Data Quality Indicators
13.	Corrective Action
14.	QA Progress Reports to Management
15.	References

3.2.1 Data Management

Data validation will follow guidelines described by the U.S. Environmental Protection Agency (U.S. EPA, 1978, 1980). The validity of the data will be checked as follows: Data will not be removed unless there is a good reason or the measurement is physically impossible. All data will be screened for outliers that are not within the physically reasonable (normal) ranges. We will take the following steps:

1) flagging data when significant deviations from measurement assumptions have occurred;
2) verifying computer file entries;
3) eliminating values for measurements which are known to be invalid because of instrument malfunctions; and
4) adjustment of measurement values for quantifiable calibration or interference biases.

Meteorological and PM data will be reviewed as time series plots. Rapidly changing, anomalous or otherwise suspect data will be examined with respect to other data at this and nearby meteorological monitoring stations to determine their validity.

3.2.2 Quality Assurance/Quality Control

- Documentation

A logbook will be maintained at the site and all relevant calibrations, experimental procedures and observations will be recorded. Separate data sheets will be maintained for entering filter sampling data and instrument QC checks. If necessary and after transferring the data to a spreadsheet maintained on a PC, we will apply calibration factors to data. After weighing, the filters will be stored in a Petri dish for storage under refrigeration. A copy of the sampling form will accompany the sample and each movement and change in custody will be noted on this form. PM concentrations will be calculated from the completed filter sampling form and also entered into the spreadsheet.

- PM Sampling Equipment

The Dustlite has an automatic zero feature and the zero will also be checked each site visit.

Quality control for the filter samplers will consist of a several different checks:

- Triple weighing of all filters before and after sampling
- Field blanks (3-5%) to assess overall blank levels and variability
- Collocated field samples (10%) to assess measurement precision

PM samplers will be calibrated against a dry test meter that has a primary calibration traceable to the NIST standard. The dry test meter will be installed at the inlet to the filter holder with a filter in place. Four nominal flow rates will be used (40, 80, 100, 120 L/min for PM$_{2.5}$ and 5, 10, 15, and 20 L/min for PM$_{10}$). The flows will be determined over a one-minute nominal period timed with a handheld digital stopwatch. Flow rates will be converted to standard conditions of temperature and pressure and a calibration equation obtained from a linear regression of the data. Temperature will be determined on-site with a thermometer traceable to the NIST standard while site pressure will be calculated from the altimeter setting obtained at the Riverside airport and adjusted for differences in elevation (using a topographic map).

- Meteorological Sensors

The wind anemometers will be calibrated by attaching a synchronous motor to the cup shaft as described in the manual. Factory conversion factors to convert rpm to speed will be used to generate a calibration curve by comparison with the readout of the data logger. Application of this calibration will be applied, if necessary, during data post processing. The wind sensors will be aligned with true north using a compass mounted on a tripod. Response will be verified by comparing the data logger output with compass measurements while the sensor is held at the four cardinal directions. The temperature sensor will be calibrated by immersing the sensing element in water in close proximity to a NIST thermometer. Three nominal temperatures will be used, 0, 20, and 40 degrees C. The relative humidity sensor will not be calibrated but the response will be verified by means of QC checks using a sling psychrometer.

3.3 On-Vehicle Real-Time PM Emission Measurements

The meteorological sensors will be calibrated as described in Section 3.1. After the wake sampling using a test aerosol we will choose an optimum sampling point for each vehicle speed. This optimum point will be located where the concentration is not changing rapidly with position and a point that represents the mean concentration of the PM in the wake. If necessary, an appropriate factor will be determined to normalize the concentration at the point with the mean.

For on-vehicle testing we will calculate the $PM_{2.5}$ and PM_{10} emission rates by dividing the concentration at the optimum point by the wake volume by the size of the wake determined in the optimization tests. We will calculate the emission rates from the fixed monitors using our dispersion model and compare with the on-vehicle data using a non-parametric statistical test. We will determine the precision of each method from collocated sampling.

The instrumented vehicle will be used to sample three types of roads, an intersection and two traffic conditions in triplicate at a minimum for both $PM_{2.5}$ and PM_{10}. Emission factors will be calculated at one-minute intervals for a minimum of ten minutes using our dispersion model.

3.4 Trackout Emission Measurements

$PM_{2.5}$ and PM_{10} emission rates from two types of trackout, directly from a vehicle and that artificially place on the pavement, will be determined by using both the fixed site and instrumented van. The emissions will be monitored until they reach a baseline. Triplicate experiments will be perform monitoring for $PM_{2.5}$ and PM_{10} .

3.5 Reporting

Quarterly progress reports will be written to review the work conducted and describe any problems encountered. A work plan will be submitted for review and acceptance prior to initiating the study. A draft final report will be written in accordance with the ARB guidelines. This will consist of the following main components:

- Description of the objective and approach.
- A summary of the data collected and estimates of precision and accuracy.
- Summary and conclusions.

The final report will include a summary of all the data and calculations of the emission factors from the passive and active sampling. We will estimate the overall accuracy of the method and its suitability as a routine method for determining PM emission factors. In addition all data will be provided on floppy disks in a format specified by the ARB.

The final report will incorporate the comments provided by the ARB in reviewing the draft final report.

4. Detailed Work Plan

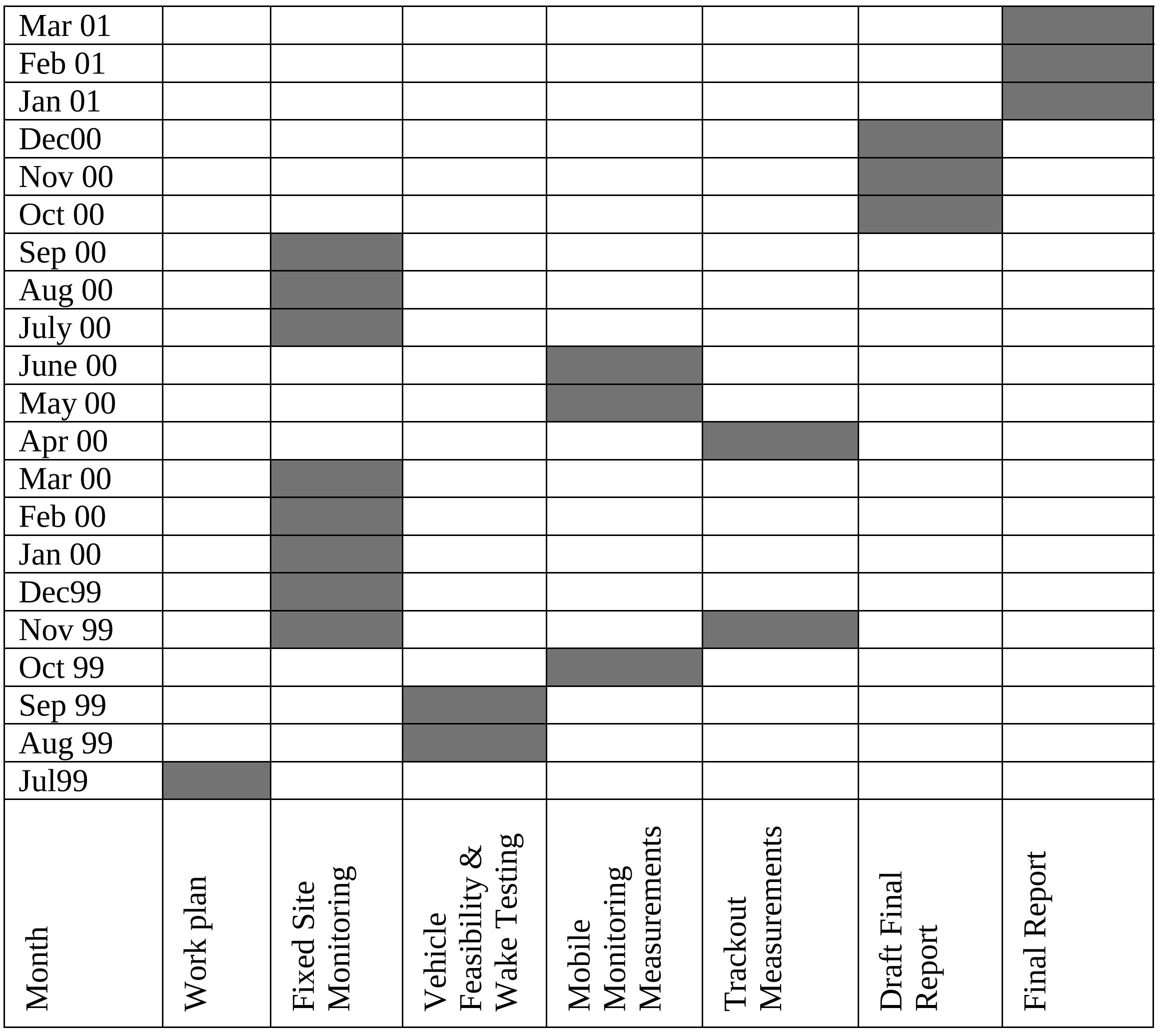
Figure 4-1 presents a detailed work plan in the standard Air Resources Board format.

Figure 4-1. Detailed Work Plan.

5. Project Schedule

Figure 5-1 is a Gantt chart showing the schedule for the project. We assume that funding is made available on July 1, 1999, and that the project will continue until March 31, 2001.

Figure 5-1. Project Schedule.



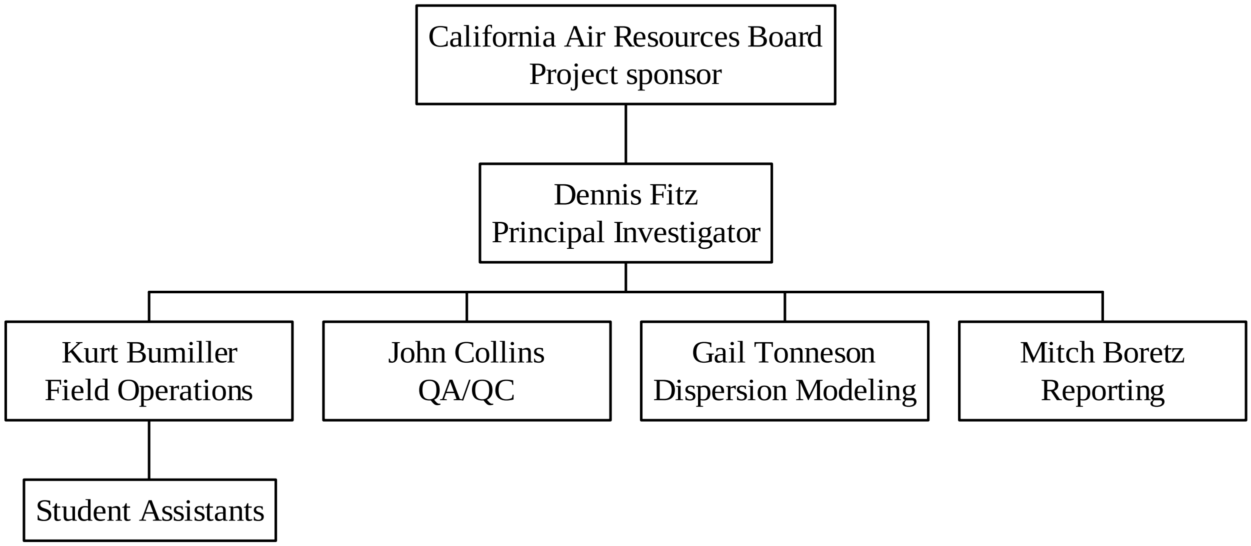
6. Project Management Plan

The following describes the key members of our research team, delineates their role in the project, and summarizes their experience and qualifications. More detailed resumes are included in Appendix A. The organization chart for this project is shown in Figure 6-1.

Mr. Dennis Fitz, the manager of Atmospheric Processes and Stationary Source Emission Control, is the proposed Principal Investigator and will be responsible for conducting the project on schedule and within budget. He also will be the primary contact between the CE-CERT team and the ARB and District staff, and will write the monthly progress reports and participate in any meeting with the ARB. The Principal Investigator will write the work plan and final reports. Mr. Fitz has extensive experience in developing sampling methods for particulate collection and in managing air quality monitoring research studies. He has advanced degrees in both chemistry and applied sciences with specialization in air pollution. Mr. Fitz has over 20 years of air quality monitoring experience at UCR and previously at AeroVironment. He has designed the samplers used for particle collection used in the SCAQS, SCENES, VAQS, NGS, Biosphere 2, and other studies and had a major role in the monitoring activities for these projects. He has pioneered denuder technology for reduction of artifacts in organic aerosol measurement and for acidic species measurement. He has evaluated the performance of particle/gas samplers used for the ARB's California Acid Deposition Project and Epidemiological Study and developed a fabric diffusion denuder for the ARB. He recently managed major field measurement programs of SCOS97-NARSTO.

Mr. Kurt Bumiller joined CE-CERT from AeroVironment Inc. and has more than twenty years of experience in conducting field studies. He will be the lead CE-CERT field technician. As an air quality scientist at AeroVironment, he specialized in setting up air quality monitoring instrumentation and performing field troubleshooting and repair. He has extensive experience in air quality measurements using aircraft. Data acquisition by remote computer control and auditing procedures are his particular specialties. He also helped to set up the nationally-recognized AeroVironment auditing department methodology and is an experienced auditor. Mr. Bumiller played a significant role in most of the major field monitoring programs conducted at AeroVironment over the past twenty years. These include PEPE-Neros, SCCCAMP, SCAQS, SCENES, NGS Visibility Study, Sacramento and San Diego ozone studies, the SVAQS/AUSPEX studies, and SCOS97-NARSTO. Mr. Bumiller will be responsible for the field sampling component of the study.

Figure 6-1. Project Organization



7. Related Research

Appendix B gives an overview of the research being conducted at CE-CERT. Listed below are some current and recent research projects of the Atmospheric Processes Group. Further details of all the projects are included in Appendix C.

- Field Study to Determine Limits of Best Available Control Methods for Fugitive Dust Under High Wind Conditions, sponsored by the South Coast Air Quality Management District
- Experimental Studies of Atmospheric Reactivities of Volatile Organic Compounds, sponsored by the Coordinating Research Council and the National Renewable Energy Laboratory
- Measurement of Street Sweeper Collection Efficiency and PM$_{10}$ Generation, sponsored by the Coachella Valley Association of Governments
- Further Evaluation of a Two-Week Sampler for Acidic Gases and Fine Particles, sponsored by the California Air Resources Board and the Coordinating Research Council
- Evaluation of a Sampling Methodology for Acidic Species, sponsored by the California Air Resources Board and the Coordinating Research Council
- Turf Overseeding Study, sponsored by the South Coast Air Quality Management District
- Evaluation Study of the CADMP Acidic Gas Sampler, sponsored by the California Air Resources Board
- Characterization of Particulate Emissions from Gasoline-Fueled Vehicles, sponsored by the California Air Resources Board
- Smog Chamber Evaluation of Alternative Fuel Vehicle Emissions, sponsored by the South Coast Air Quality Management District

- Measurement and Modeling of PM$_{10}$ and PM$_{2.5}$ Emissions from Paved Roads in California, sponsored by the California Air Resources Board
- Investigation of the Atmospheric Ozone Formation Potential of Chloropicrin, sponsored by the Chloropicrin Manufacturers' Task Force
- Site Support for the National Ultraviolet Monitoring Center, sponsored by the University of Georgia
- Investigation of the Atmospheric Ozone Formation Potential of Methyl Acetate, sponsored by the Eastman Chemical Company
- Investigation of the Atmospheric Ozone Formation Potential of Trichloroethylene, sponsored by the Halogenated Solvents Industry Alliance, Inc.
- Investigation of the Atmospheric Ozone Formation Potential of Selected Dibasic Esters, sponsored by the Dibasic Esters Group
- Investigation of Atmospheric Reactivities of Selected Stationary Source VOCs, sponsored by the California Air Resources Board
- Investigation of Atmospheric Ozone Formation Potentials of Selected Aluminum Rolling Lubricant Constituents, sponsored by the Aluminum Association
- Experimental Evaluation of Ozone Forming Potentials of Motor Vehicle Emissions, sponsored by the California Air Resources Board
- Evaluation of Street Sweeping as a PM$_{10}$ Control Method, sponsored by the South Coast Air Quality Management District
- Measurement of Nitrogenous Species and Solar Intensity during the 1997 Southern California Oxidant Study.
- Surface and Upper-Air VOC sampling and analysis during the 1997 Southern California Oxidant Study.
- Performing Ozonesonde Measurements for the Southern California Oxidant Study.
- Analytical Support for the California Regional PM$_{10}$ Air Quality Study-Technical Support Study 15.
- Further Testing and Analysis of the PremAir Catalyst for Stationary Source Applications.
- Evaluation of the PM and Ozone Producing Potential of Natural Gas-Powered Vehicles.

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Appendix A: Biographies of Key Personnel

Appendix B: CE-CERT Overview

The University of California, Riverside established a Center for Environmental Research and Technology with a major focus on air pollution. The Center is a division of the College of Engineering and closely associated with the Statewide Air Pollution Research Center (SAPRC). The Center creates a new form of university/industry/federal and state agency interaction intended to facilitate more rapid transfer of air pollution control technology and to provide independent testing for new scientific technology under consideration by industry or regulatory agencies.

CE-CERT occupies a 36,000-square-foot research laboratory and has more than 60 employees and students. CE-CERT houses a Vehicle Emission Research Laboratory consisting of a 48-inch single-roll dynamometer allowing for the accurate testing of severe transient events (hard accelerations and decelerations greater than 6 mph/second), along with the appropriate pre- and post-catalyst emission measurement equipment.

CE-CERT has been strongly endorsed by the South Coast Air Quality Management District, the California Air Resources Board, and the California Energy Commission, as well as the Department of Energy, the Department of Transportation, and the U.S. Environmental Protection Agency.

Research at CE-CERT addresses these critical areas:

<u>Atmospheric Processes:</u>

Major objectives include assessment of the environmental impact of emissions from stationary and mobile sources. Studies include the use of both indoor and outdoor smog chambers to evaluate the atmospheric reactivity and secondary products of gaseous emissions; research on the heterogeneous (i.e., gas to particle) photochemical formation and direct emissions of respirable airborne particulate and organic aerosols, and the evaluation of their impact on public health and visibility.

<u>Vehicles Emissions Research</u>:

Major objectives include evaluation of energy usage and emissions of alternative fueled vehicles and vehicles designed to meet future California emission standards; develop capability to measure emissions and vehicle parameters of vehicles on–road with on–board instrumentation; develop, evaluate, and apply remote sensing technology for mobile sources; establish environmental impact of reformulated and alternative fuels, including atmospheric reactivity, airborne toxics, global climate change, and urban/regional visibility.

<u>Environmental Modeling</u>:

Major objectives include development and application of urban and regional airshed models for South Coast Air Basin, Inland Empire, and other areas within California and the nation. These models will include state–of–the–art chemical mechanisms of important gaseous and aerosol pollutants, consideration of important gas to particle chemistry, detailed meteorology, and emission inventory for both stationary, biogenic, and mobile sources.

Transportation Systems Research:

Major objectives include development and application of enhanced transportation models that incorporate dynamic vehicle emissions data, traffic networks, and topographical data. Output of these models can be used for emission inventory evaluation, assessment of traffic flow, energy and emission estimates of traffic control strategies for freeway and non–freeway networks. This program will be closely coupled to the on–road emission program described in Vehicle Emissions Research.

Advanced Transportation Engineering:

Major objectives include the development and evaluation of environmental impact of future alternative transportation systems. This includes electric and hybrid-electric vehicles, and light- and heavy-duty vehicles operating on reformulated gasoline, natural gas, propane, hydrogen, methanol and ethanol. Topics to be addressed are design of engine and emission control systems, drivability and range, fuel packaging and control systems, material/fuel compatibility, and fuel cell technologies.

Stationary Source Emission Control:

Major objectives include development and evaluation of emission control and process control technology for VOC and NO_X emissions from stationary sources. Development of analytical instrumentation and process controls for monitoring and control of manufacturing processes, gaseous pollutants and industrial waste streams. Evaluation of environmental impact of various solvents used for coatings, cleaning, and manufacturing processes.

Renewable Energy Fuels Research and Development:

Major objectives include development and evaluation of advanced technologies associated with renewable energy and fuels including solar energy and bio-fuel conversion. Emphasis will be placed on the development and evaluation of prototype production facilities associated with transportation related fuels such as hydrogen, ethanol, methanol, and bio-diesel fuel.

Appendix C: Description of Related CE-CERT Projects

Field Study to Determine Limits of Best Available Control Methods for Fugitive Dust Under High Wind Conditions
Principal Investigator: D. Fitz
Sponsor: South Coast Air Quality Management District
Amount: $69,574 (Phase 1); 19,872 (Phase 2)
Period: 7/94 - 3/96

The EPA has designated California's South Coast Air Basin and the neighboring Coachella Valley as “serious” non-attainment areas with respect to the National Ambient Air Quality Standards (NAAQS) for PM_{10} (particulate matter less than ten micrometer aerodynamic diameter). Both of these areas are within the jurisdiction of the South Coast Air Quality Management District (District). The District is required by the 1990 Clean Air Act Amendment to prepare State Implementation Plans (SIPs) outlining the Best Available Control Methods (BACM) that are needed for the areas to achieve compliance with the air quality standards. The objective of this study was to determine the wind speed under which the BACM for fugitive dust control from construction and landfill activities become ineffective. The approach involved setting up PM_{10} sampling equipment upwind and downwind of soil pickup activity at a landfill during high wind events. The samplers were filter collection devices to measure hourly average PM_{10} according to EPA equivalency guidelines. Meteorological sensors were used to concurrently measure wind speed, direction and temperature. These measurements were supplemented with those of light scattering from an integrating nephelometer, which gave a measurement that could be related to PM_{10} concentration. In addition, the activities were monitored with a video camera to validate the BACM application and to give a direct visual comparison of dust generation with wind speed. Data were used to compare the BACM efficiency as a function of wind speed.

Measurement of Street Sweeper Collection Efficiency and PM_{10} Generation
Principal Investigator: D. Fitz
Sponsor: Coachella Valley Association of Governments
Amount: $79,912
Period: 5/95 - 6/96

The increased use of street sweepers has been proposed as a method of controlling PM_{10} emissions in the Coachella Valley. Sweepers can also be a source of significant PM_{10} emissions. Several of the latest sweeper models are designed to control these emissions. The objective of this study was to measure both the sweeping efficiency and PM_{10} emissions from four of these new models when sweeping “blowsand” from the Coachella Valley. This was done by operating the sweepers on a test track enclosed by a tent 20 feet wide, 15 feet high and 240 feet long. The purpose of the tent was to trap all of the emissions. The tent was set up with the prevailing winds directed into the inlet; fans were used when the winds were calm. PM_{10} sampling devices were operated on both ends of the tent. An inert tracer gas, sulfur hexafluoride, was released near the inlet and measured at the outlet to determine the volume of air passing through the tent. The efficiency of the sweeping was determined by vacuuming sand from a unit area and weighing it before and after each test run. As a separate task,, the use of soil stabilizers to control dust emissions from unpaved bus stops was evaluated over a one year period.

Further Evaluation of a Two-Week Sampler for Acidic Gases and Fine Particles
Principal Investigator: D. Fitz
Sponsor: California Air Resources Board/Coordinating Research Council
Amount: $141,086
Period: 7/94 - 4/96

Acidic species in the atmosphere are of concern because of effects on human health and materials. Methods to monitor these species on a routine basis involve the collection of acidic gases and fine particle ions on filter media, followed by chemical analysis. One method of measurement by ARB involves use of the Two-Week Sampler, which was designed to collect integrated 2-week sample with continuous operation throughout the year. The development of the Two-Week Sampler involved both laboratory and field testing. Candidate collection substrates were examined in the laboratory for losses of nitric acid from collection substrates during repeated exposure to hot, dry conditions, and were compared in the field against sampling substrates changed daily. Also, the completed sampler was compared against other nitric acid measurement methods over two two-week periods. These tests guided the selection of collection substrates for the sampler, but also pointed out the possibility of positive interferences expected from nitrous acid or peroxyacetyl nitrate (PAN). Thus, further evaluation of the sampler performance, beyond that already performed,, was conducted through the following tasks: determining the penetration of nitric acid through the various components (inlets, denuders, and filterpacks) of the sampler; comparing the performance of the carbonate-coated glass denuder to the sodium chloride-coated denuder under field conditions; evaluating the potential for sampling artifacts that may be exacerbated by long sampling intervals; quantifying the extent of nitrous acid and PAN interferences on the carbonate coated glass denuder as currently employed in the Two-Week Sampler; and evaluating possible positive interferences on the carbonate back-up filter.

Evaluation of a Sampling Methodology for Acidic Species
Principal Investigator: D. Fitz
Sponsor: California Air Resources Board/Coordinating Research Council
Amount: $311,767
Period: 7/94 - 7/96

The objective of this project is to present a plan for the comprehensive measurement of species related to acid deposition that will allow measurements to be made at lower cost with improved accuracy compared respect to current methods. The basis for this plan is a novel diffusion denuder being developed at CE-CERT. This denuder is based on a physical structure that allows it to be very low cost, compact, and adaptable to most types of particulate samplers. We propose using a combination of denuder and filter coating substrates in one or more sampling cassettes that will simplify the collection methodology. The denuder and substrate performance is being thoroughly evaluated under laboratory and field conditions for accuracy, precision and interferences. The inherent simplicity of the sampling approach will allow samplers to be built that are less costly and more reliable, durable, and easier to service than those currently in use. The sampling methodology will be flexible, so that the collection substrates, flow rates, and sampling durations may be chosen to meet future air monitoring objectives.

Turf Overseeding Study
Principal Investigator: D. Fitz
Sponsor: South Coast Air Quality Management District
Amount: $48,994
Period: 11/94 - 12/95

Most of the more than 80 golf courses in the Coachella Valley prepare their turfs for the winter by allowing the summer Bermuda grass to die out, using a turf raker to remove debris, and then overseeding with rye grass for the winter. The operation of the turf raker produces large quantities of visible dust emissions. The objective of this study was to quantify PM_{10} emissions with and without a water spray device used for their control. This was done by sampling with portable PM_{10} collection devices at the sweeper outlet and at upwind and downwind locations. Integrating nephelometers were also placed upwind and downwind to provide a measure of PM_{10} in near real-time. The amount of PM_{10} generated was calculated after measuring the volume of air emitted by the turf raker.

Evaluation Study of the CADMP Acidic Gas Sampler
Principal Investigator: D. Fitz
Sponsor: California Air Resources Board
Amount: $104,803
Period: 7/94 - 4/96

The California Acid Deposition Monitoring Program (CADMP) was implemented by the California Air Resources Board (ARB) to meet a legislated mandate to assess levels of acidic deposition within the state. The program addresses wet deposition (from precipitation) and dry deposition (which arises from processes such as turbulent diffusion or settling). To meet the monitoring needs, a special acid sampler (CADMP sampler) was built and installed at 10 sites in California during 1989. Due to concerns raised from data analysis and limited field comparison studies, CE-CERT performed a study to understand sources of errors inherent with the CADMP sampler. The tests included laboratory and field evaluation of the penetration of nitric acid through the sampler, evaluation of the cutpoint of the sampler's size selective inlet, and comparison of the sampler with spectroscopic measurements of nitric acid.

Measurement and Modeling of PM_{10} and $PM_{2.5}$ Emissions from Paved Roads in California
Principal Investigator: D. Fitz
Sponsor: California Air Resources Board
Amount: $249,757
Period: 7/95 - 3/97

The objective of this project is to develop a more reliable method of estimating PM_{10} emissions from paved roads. The currently used algorithm is not dimensionally correct, has large error potential, and has never been validated in California. In the first phase, we are collecting data for emission rates based on upwind/downwind sampling for PM_{10} and will compare the results with the existing algorithm. Based on these collected data, we will formulate a new model for calculating emissions and validate it with further data from actual paved roads. The model will be developed by first using mass balance or dispersion modeling techniques and then by empirically applying multivariate regression of emissions against the variables expected to be responsible.

Evaluation of Street Sweeping as a PM10 Control Method
Principal Investigator: D. Fitz
Sponsor: South Coast Air Quality Management District
Amount: $84,904
Period: 5/96 - 9/97

The primary objective of this project is to determine the effectiveness of street sweeping as a method of PM_{10} control. A secondary objective is to acquire additional data to validate a model being developed under funding by the California Air Resources Board to estimate PM_{10} emissions from paved roads. These emissions are difficult to quantify, and correct algorithms for estimating them have not been validated for the South Coast Air Basin. The effectiveness of various sweepers in controlling PM_{10} has not be established and therefore street sweeping cannot be considered a control technology. While the premise that particulate matter is removed by sweeping is logical, there is no direct evidence of the usefulness of street sweeping to control these emissions. We are proposing the evaluation of street sweeping as a PM_{10} control measure using a new and innovative approach. The primary benefit to the SCAQMD will be an estimate of the suitability of including routine street sweeping in the 1997 SIP for PM_{10}. With the proposed schedule, the data from this study will be available for incorporation into this document. When the full model is completed under ARB funding, the SCAQMD will be able to more accurately compile PM_{10} emission inventories. These inventories will be useful in determining future PM_{10} control strategies.

Appendix D: Cost Proposal

Budget Submittal Form

This form is supplied for presenting budget detail to the Air Resources Board.

PLEASE TYPE OR PRINT:

Title of Proposal: Measurements of PM10 and PM2.5 Emission Factors from Paved Roads in California

Total Budget Requested: $157,286

Period Covered (months): July 1, 1999 to March 31, 2001

Business or Institution: University of California, Riverside
Office of Research Affairs

Address: Riverside, CA 92521-0425

Name of person authorized to bind this bid: David Serrano

Title: Assistant Director
Offfice of Research Affairs

Phone: (909) 787-5535
(909) 787-4483 FAX

Signature of person authorized to bind this bid: ______________________

Statement of Accounting Practices

Have you used federally-approved or lower rates or schedules for computing overhead or other indirect costs for this proposal?

[x] YES [ ] No

If yes, please and include a copy of the letter from the reviewing agency approving the rates used for this proposal. If no, please give the reasons below and explain how your rates are competitive.

Budget Summary*

Direct Costs

1. Labor & Employee Fringe Benefits	$ 92,234	
2. Subcontractors & Consultants	$ 0	
3. Equipment	$ 23,500	
4. Travel and Subsistence	$ 1,985	
5. Electronic Data Processing	$ 0	
6. Photocopying & Printing	$ 1,000	
7. Mail, Telephone & FAX	$ 500	
8. Materials & Supplies	$ 13,000	
9. Analyses	$ 0	
10. Miscellaneous	$ 14,196	
Total Direct Cost		$ 146,414

Indirect Costs

11. Overhead	$ 10,872	
12. General & Administrative Expenses	$	
13. Other Indirect Costs	$	
14. Fee or Profit	$	
Total Indirect Costs		$ 10,872

Total Direct and Indirect Cost: 157,286